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WHAT'S BEHIND DoD's NEW EMPHASIS . . .

ON FLIGHT SIMULATION

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The COMING PAYOFFS of IMPROVED FLIGHT SIMULATORS

BY DR. JOHN L. ALLEN
Deputy Director of Defense Research & Engineering

It is a pleasure to present an overview of the Department of Defense (DoD) programs on flight simulation, what DoD believes are the likely payoffs of improved flight simulators, and what the Defense Department believes are the key research and development (R&D) questions.

Three of the four cognizant Congressional Committees for DoD have expressed interest in the Department's programs for flight simulation equipment. The Senate Armed Services Committee Authorization Report for Fiscal 1976 expressed concern regarding the potential degradation of the quality of the flying force due to use of simulators as a substitute for flying. Conversely, the Conference Committee on Appropriations was concerned with assuring that the Department aggressively pursue the integration of flight simulators into the training programs, and with the impact of increased adoption of simulators.

In response to previous direction by the Senate Armed Services Committee, DoD has furnished a report on its flight simulation procurement program for Fiscal 1976 and Fiscal 1977. This presentation covers the overall DoD flight simulator program, focusing on the research and development program aspects. Emphasis will be placed on an assessment of how the R&D program interfaces with the procurement program, and on R&D relating to the proper use of simulators to develop and maintain aircrew proficiency and increase combat readines.

THREE MAJOR OBJECTIVES

There are three major objectives in the development of flight simulators. These are:

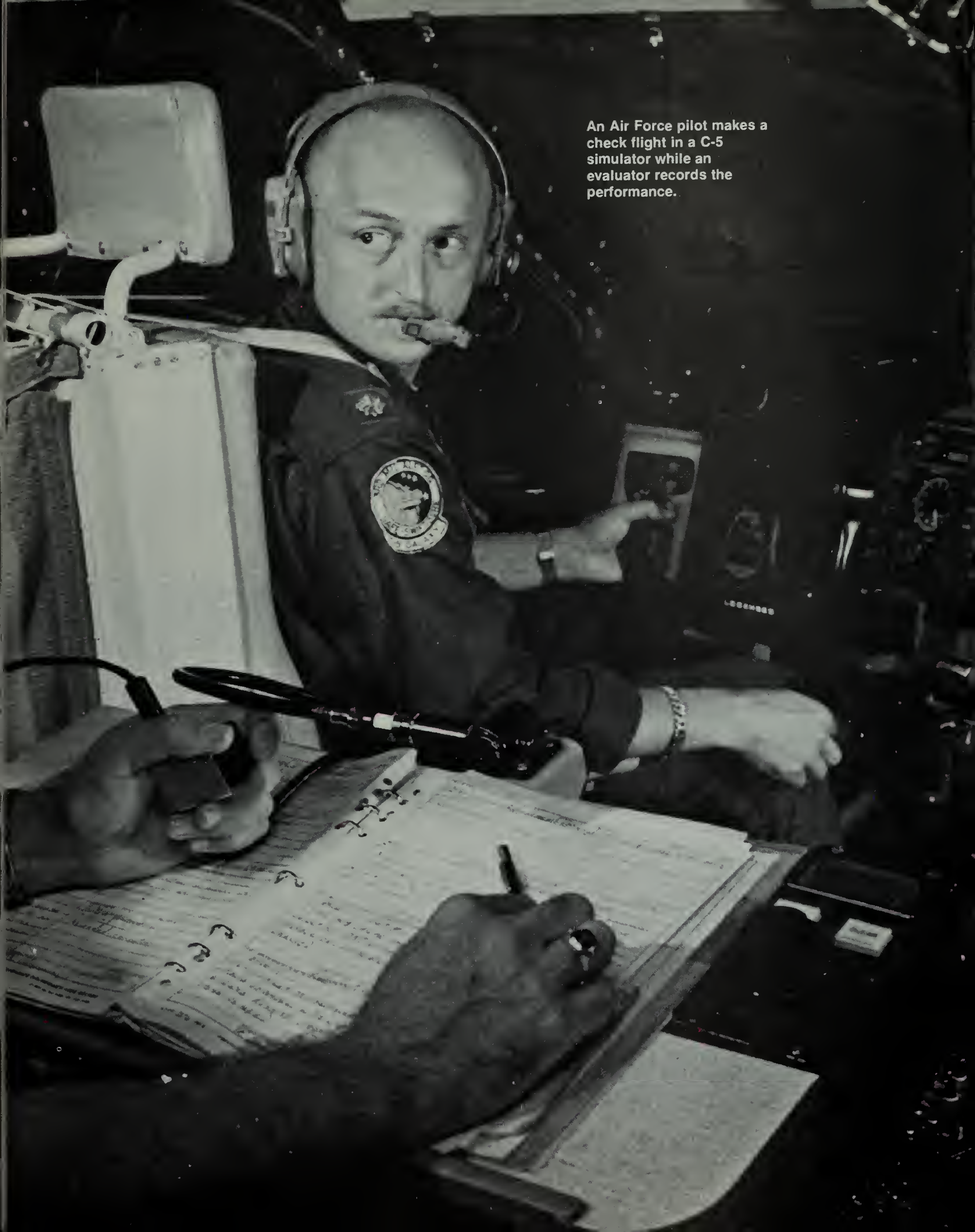
- the development of better pilots and aircrew members,
- the maintenance and improvement of combat readiness in experienced aircrews, and
- the reduction of training and operating costs.

Each of these objectives will be elaborated on here. However, it must first be well understood what the distinction is between the military needs from flight simulators and what the airline industry attempts to achieve.

It is well known that the airline industry, building on early DoD work, has been spectacularly successful in the use of simulators for pilot transition training and proficiency testing to reduce non-revenue airborne flight training. Pilot proficiency has been maintained, and operating costs to achieve this proficiency have been reduced. Some of DoD's military flying closely parallels airline flying, especially that of maintaining proficiency of transport pilots. The Defense Department can and does exploit the civilian airlines' experience for these missions. In comparison, however, it should be noted that airline pilot hours per month in the cockpit on revenue flights are still typically significantly higher than hours for military pilots flying transport aircraft.

In other aspects, Defense needs differ from those of the airline industry, sometimes dramatically. First the civilian airlines use simulators almost exclusively for the purpose of training already highly experienced pilots to fly new types of aircraft—that is, for transition training as opposed to teaching basic skills or maintaining readiness. In contrast to the airlines, the purpose of a substantial portion of military flight training is to transform novices into pilots, navigators, electronic warfare operators, sensor operators, and other aircrew members through undergraduate training. Secondly, with the exception of routine airlift missions and some other military flying missions which are

ABOUT THE COVER—This operational flight trainer is a replica of the Navy P-3C cockpit. The visual display on the windshield is computer-controlled to simulate 50 landing fields throughout the world, under all kinds of lighting conditions.



An Air Force pilot makes a check flight in a C-5 simulator while an evaluator records the performance.

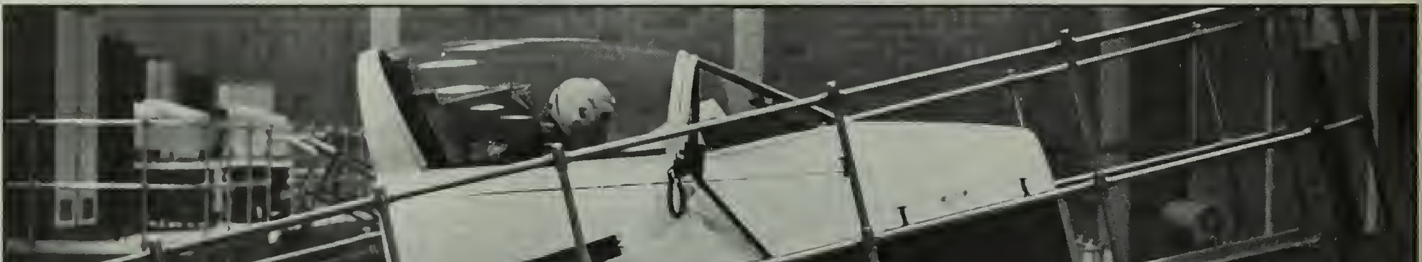
reasonably similar to typical airline flying, military flying is generally much more complex than airline flying and often is highly dependent upon complicated crew and mission coordination.

DIFFERENT TYPE MISSIONS

The military pilot and other aircrew members must be capable of performing tasks not required of airline pilots and crews. For example, depending on the type of aircraft to which they are assigned, military aircrew members must be able to perform map-of-the-earth flying, aerial delivery of cargo or personnel, carrier or short field take-off and landing, air-to-air and air-to-ground weapon delivery, in-flight refueling, low-level strategic bomb runs in an electronic countermeasure environment, and other peculiar mission-related tasks under actual combat conditions. These missions place greatly increased demands on what must be simulated for effective training, especially in terms of the visual and sensor simulation requirements and motion "cues", and in terms of the need for effective crew coordination.

It should also be appreciated, for background purposes, that the term "flight simulator" is casually used to describe the full range of equipment, from the very sophisticated device employing the most advanced technology to the simple procedural trainer. The potential a particular device has for providing mission effective training and cost savings depends on the complexity of the problem to be simulated and the capability of the

The Navy's flight trainer for the T-2C "Buckeye" aircraft is operational at Naval air stations in Texas, Mississippi, and Florida.



device. At the upper end of the spectrum is the sophisticated device which reproduces, to the greatest extent possible, the complete capability and environment of a specific aircraft or system or a specific mission. A device of this type provides individual and/or crew training in all aspects of the operational mission under visual or instrument conditions. These devices are equipped with visual displays that depict, over a wide angle, the view of the surrounding airspace and ground, which the crew would see while performing its mission. They also are capable of simulating the motion and many of the other sensations of the actual aircraft with the motion and visual scene carefully coordinated.

These devices are expensive and represent the upper bounds of simulation at the current state of technology. The Department of Defense has very few devices which approach this ideal, although a concentrated program is underway by DoD to develop and procure devices of this type in substantial numbers as needed to support the training missions requiring this level of fidelity. At the lower end of the equipment capability spectrum is the procedural or part-task trainer. These devices provide students the opportunity to become familiar with, and to develop limited proficiency in the operation of a particular function or part of a total system. These devices may simulate the actual equipment only as far as external configuration and will not necessarily respond to trainee control inputs. These trainers are made as simple as possible, are the least expensive, and do not normally possess visual or motion systems. These devices are not a substitute for any significant number of flight hours, but they are very important in the total training program of aircrews.

INFLUENCING FACTORS

Let us consider the factors which have influenced the increased DoD emphasis on simulation. The Defense Department believes that the use of simulators in place of some flight time will allow the development of new aircrews with military skills, and will also allow DoD to maintain or enhance those skills more effectively in experienced aircrews. Simulators make it easy to demonstrate the ideal form of various maneuvers and procedures. They allow students to learn and to practice repeatedly such maneuvers in a short time and make possible both "instant replay" and statistical analyses based on quantitative measurement of their performance by use of the recorders and computers that are integral to such systems.

Flight crews are able to practice maneuvers safely in the simulator that would approach the edge of the operating envelop without risk. Simulators also allow us to simulate emergency situations, the actual execution of which would pose a serious hazard to personnel and equipment. They even allow us to model being shot at very realistically by homing surface-to-air missiles (SAM) for practice of evasive maneuvers.

Much has been said about the economic aspects of the use of simulators and numerous analyses have validated that significant savings can be expected. In addition to direct savings in fuel and other operating costs, indirect savings can also be anticipated, including reduced wear and tear of equipment as well as reduced loss of personnel and equipment due to the inevitable occasional accident. Furthermore, DoD believes that the increased availability and use of simulators in undergraduate flight training may, in effect, increase effective use of runways and airspace. This may, in combination with other factors, permit us to devote fewer bases to undergraduate flight training, with attendant savings in support facilities and manpower. These examples of potential indirect savings are intended only to initiate a dialogue in this area. It will be necessary to concentrate future R&D and operational attention to

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Born in Estherville, Iowa, June 13, 1931, Dr. Allen was graduated from Pennsylvania State University in 1958 with a B.S. degree in engineering science, and from Massachusetts Institute of Technology with an M.S. degree in electrical engineering in 1962 and a Ph.D. in communications biophysics in 1968.

He joined the Research Department of the Naval Research Laboratory as the Associate Director of Research for Electronics March 1, 1971.

His professional experience began with the U.S. Air Force (1950–1954)—two years as a student and an instructor at the Air Force Radar School and two years at Massachusetts Institute of Technology Lincoln Laboratory. While attending Pennsylvania State University, he was employed as an engineer by HRB Singer, Inc. After graduation, he returned to Lincoln Laboratory as a staff member and advanced to the position of Associate Head of the Radar Measurement Division.

His fields of interest at Lincoln Laboratory were antennas and radar systems research. He organized and was the first leader of Lincoln Laboratory's Array Radars Group. His Ph.D. thesis was concerned with the optics of the compound eye of the invertebrates.

Dr. Allen is a fellow of the Institute of Electrical and Electronic Engineers, past IEEE National Lecturer on Microwave Theory and Techniques, and a member of the Tau Beta Pi Engineering Honor Society. He has served on and led several studies and committees for professional societies and for the Department of Defense.

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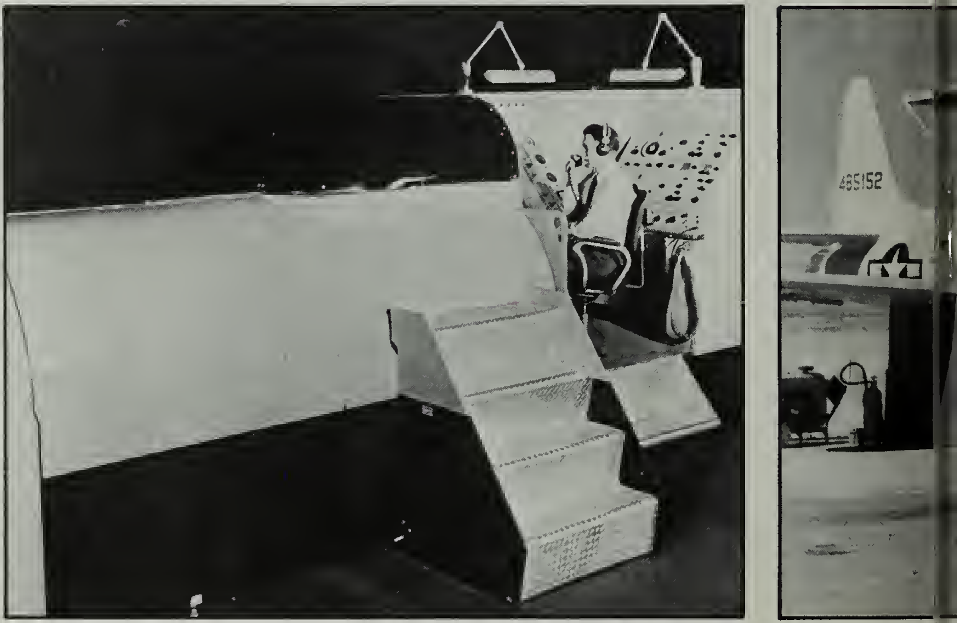
demonstrate and quantify these factors.

Let's emphasize again, however, that both the initial and primary interest in simulators is for the opportunity that DoD believes modern simulation affords, if properly used, to produce a better end product.

The Department of Defense interest in flight simulators goes back many years prior to the current drive for economy.

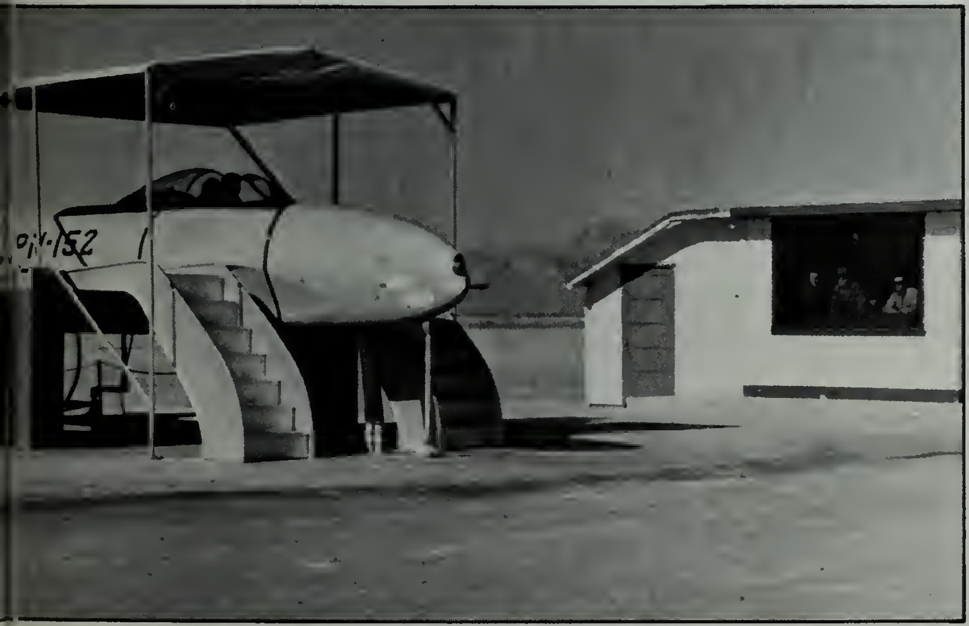
HISTORICAL HIGHLIGHTS

Ed Link developed the first flight trainer, called ''The Pilot Maker,'' in 1929. The effective use of simulation in training, however, began with the use of the Link Trainer during World War II to increase instrument flying proficiency. These early mechanical devices were replaced with systems using electronic advances during the late 1940s. In 1949, under the sponsorship of DoD, the effective use of simulators was demonstrated by the Aviation Research Laboratory at the University of Illinois. The AC analogue flight simulator was developed for training during the early 1950s, and used until the late 1950s. Examples of aircraft simulators



The C-11B flight trainer (left photo) was the first jet trainer to be produced in quantity. The "Captivair" P-80 device (right photo) subjected the aviation cadet to the misfortunes that could occur in the Lockheed P-80 fighter aircraft in flight, and recorded his corrective actions.

The Link Trainer department at Randolph Field, Texas (left) was called the "West Point of the Air." A pilot (below) exhibits the fine points of aerial gunnery on a gun-equipped Link Trainer. The Link Trainer was named for Ed Link who developed the first flight trainer, called "The Pilot Maker," in 1929.



developed during this period include the F-9F, P-2V, B-52, and KC-135.

The DC analogue system was introduced in the late 1950s and was used almost exclusively until the development of the digital computer. Examples of aircraft simulators developed during this period are the A-4D, F-4, and C-130. It was also during this period that the first attempts were made to simulate the visual scene. A major milestone was reached in simulator progress by the Air Force demonstrations of the training effectiveness of simulators at Goodfellow AFB, Texas, during the early 1950s.

The feasibility of real time digital simulation for flight training was demonstrated during the early 1960s. The weapon systems simulators developed using this early digital capability were the C-141, F-111, and A-7A. The development of a terrain model board and TV approach for visual simulation was also initiated during this period. Early Service attempts to implement this form of visual simulation for training were largely unsuccessful due to poor aerodynamic quality of simulation and poor image quality of the visual system. The commercial airlines, however, applied this technique successfully during the mid to late 1960s. American Airlines and United Airlines activities are considered important landmarks in demonstrating effective use of simulation during this period.

Also, in 1969, Apollo 11 landed on the moon, validating on the first flight the effective use of total simulation in the training program. Apollo success thus represented the culmination of a major program of development and application of new technology to full mission simulation by the National Aeronautics and Space Administration (NASA).

During the 1970s, the second generation digital simulators, including the C-5, were developed. Other simulator complexes such as the T-2C and U-H1, which are multi-unit devices tied to a central computer, were developed. Technology now permits full six degree-of-freedom motion bases and sophisticated visual systems. The Army, during type classification of the U-H1 simulator at Ft. Rucker, demonstrated that a pilot could be adequately trained in a simulator alone to pass an instrument flight check in the helicopter.

We have progressed a long way from the initial Link trainer. Flight simulation is achieving a degree of realism, even in the most demanding arena of full tactical mission simulation, that is impressive even to the experienced aircrew. These achievements are, of course, the results of the total R&D program of DoD, NASA, universities, civilian aviation, and the airline industry.

The Defense Department R&D program is now concentrating on the military unique aspects of flight simulation and is focused on three principal R&D questions:

- How faithfully will technology allow us to simulate the various aspects of a real flight mission?
- How much fidelity is enough?
- How can we best use such devices in our total training program?

These three questions are, of course, all intimately related with each other and with the basic procurement program as well. It should be pointed out that Defense's early R&D focus on technology is shifting to the latter two questions.

TWO SEPARATE EFFORTS

DoD divides flight simulation and flight training R&D into separate efforts for fixed wing platforms and rotary wing platforms. Most of the R&D in advanced simulators for fixed wing platforms is presently carried out by the Air Force; specifically the Human Resources Laboratory for the technology base efforts and the Simulator System Program Office for engineering developments. The Navy, which has made significant earlier contributions, now has a smaller program primarily in the technology base area, addressing some complementary questions, with the work primarily focused at the Naval Training Equipment Center and with some work at the Naval Personnel Research and Development Center. The rotary wing program is primarily executed by the Army under the Program Manager for Training Devices and the Army Research Institute. It is significant that each Service team consists of a hardware oriented group and a human factors oriented group.

This reflects the Defense Department's concern both with the technical aspects and the performance of the devices and the trainees. DoD simulation activities are coupled to NASA activities at the Ames Center where the Army Air Mobility Laboratory is collocated, and at the Langley Center where the Air Force Tactical Air Command is the host.

As one might anticipate, the R&D program is addressing many pertinent issues. However, the focus is on a few critical areas.

In technology, the most critical issue is how best to provide wide-field-of-view, high resolution visual systems for simulators with the current emphasis on how best to generate the imagery and to display it. The answers will, of course, depend upon the type of mission to be simulated, upon the field-of-view required for each mission being a critical factor, and upon the cost and complexity of the current and evolving state-of-the-art and technology. DoD has been evolving for many years the capability to generate the imagery by the use of TV probes and model boards—now the art of computer generation of imagery is growing rapidly. Defense has for years been displaying imagery by projection on domes or screens mounted around cockpits. Recent technological advances have demonstrated the possibility of integrating large cathode ray tubes with complexed, in-line optical systems for wrap-around displays. Substantial advances have been and are being made in all of these areas.

An additional area of technological focus is on simulating other sensors, such as low light level TV, infra-red (IR), radar, and sonar.

On the issue of how much fidelity is enough, R&D is devoted predominantly

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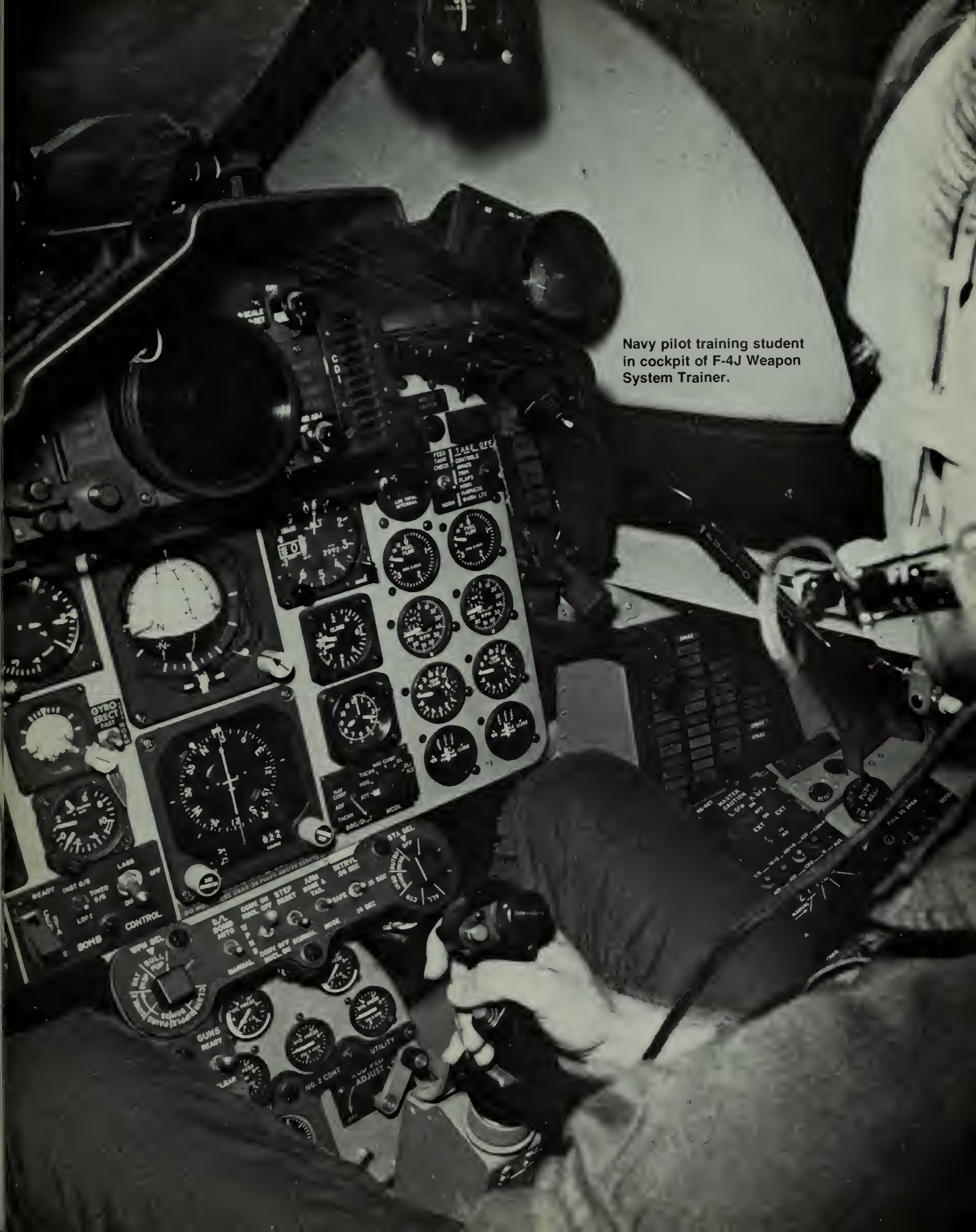

Navy pilot training student in cockpit of F-4J Weapon System Trainer.

The funding profile for the three Services is described in chart.

RDT&E
($ in millions)

	Programmed			Request	Planned
	FY 75	FY 76	FY 7T	FY 77	FY 78
Army	3.1	4.0	1.3	7.1	8.1
Navy	4.6	3.8	1.1	4.9	5.5
Air Force	11.7	9.1	2.6	19.2	33.0
TOTAL	19.4	16.9	5.0	31.2	46.6

PROCUREMENT
($ in millions)

	Programmed			Request	Planned
	FY 75	FY 76	FY 7T	FY 77	FY 78
Army	11.0	17.0	—	14.5	54.2
Navy	133.5	42.4	23.2	82.4	89.8
Air Force	124.9	139.5	10.3	231.6	398.1
TOTAL	269.4	198.9	33.5	328.5	542.1

to the question of interaction of simulator motion and simulator visual capabilities and the optimum trade-offs between these capabilities for various missions. Success is measured by the effectiveness of training, as determined by painstaking and extensive experiments on transfer of training from simulators to aircraft, as a function of proficiency and cost.

As indicated previously, DoD has made a major shift in R&D program emphasis so that a substantial part of the program is concerned with the questions of how flight simulators can best be used in an integrated flight training program and to what degree they can replace flying time. A very real complication is that the question is not entirely answerable by R&D. Defense is exploring the question of the dependence of flight crew expertise on simulator usage.

However, the real issue is combat effectiveness of the flying force. This effectiveness is dependent on a total team effort. Equipment, aircrews and ground support are integral parts of any successful combat operation. This integrated effort can not be exercised through flight simulation. Consequently, DoD knows that it will never be able to substitute simulators to the degree that would be possible if the only concern were the training of the flight crews themselves. Thus, while DoD is concentrating a substantial effort of the R&D program upon the question of simulators in the flight crew training program, it must be cautioned that an extended evolutionary learning phase will be required to arrive at really constructive answers regarding the impact of simulators on flight hours.

Hopefully, it is clear at this point that caution is exercised in applying simulators to flight training in such a way that the quality of DoD's flying force is enhanced and not degraded. The R&D program is directed at learning how Defense can better use, as well as better design, simulators and this information is being applied to the procurement program in a manner and with a degree of success that will be touched on briefly.

An analysis of the relationship of R&D funding to DoD procurement funding indicates that in recent years the R&D funding has been a little less than 10 per cent of the procurement funding. That may be an appropriate ratio if the interactions between R&D and the operators are carefully orchestrated. Defense achievements in this area are mixed for reasons that will be described briefly. Officials in the R&D community see their principal function as being one of providing quantitative information and demonstrations of what is technologically possible, how much it will cost, and what benefits can be expected from demonstrated technology to assist operators (and hence the procurement people) in the decision process. Unfortunately, we never know as much as operators would like. That is a general R&D truism and is particularly true in the flight simulation area.

Performance assessment in either a simulator or an airplane is a difficult problem. DoD's current R&D programs are providing information which is increasing the confidence in the procurement and use of simulators. However, it should be borne in mind that before the stimulus of the fuel shortage, it was difficult to get support for an aggressive flight simulator R&D and procurement program.

An instructor at his station in the Navy's P-3C Operational Flight Trainer checks the performance of the pilot.

The Defense Department is extremely fortunate that NASA and the civilian airlines did as much as they did during this period. Then in the late 1960s, it became apparent to some in DoD that much more could be done in the more demanding military application. In 1967, DDR&E directed that the Services establish a broader training and simulation R&D program to enhance combat training and reduce training costs.

One of the hallmarks of that program now is the Air Force's Advanced Simulator for Undergraduate Pilot Training (ASUPT) which today represents the pinnacle in the state-of-the-art in full mission simulation capability. It had its birth in studies done in 1968, leading to a contract in 1970, and a delivered simulator in 1975. However, the increased DoD emphasis in the procurement and use of simulators really dates from the fuel shortage in 1973.

The fuel shortage hit in earnest in 1973 and interest in simulator usage suddenly increased, resulting in a request for a substantial increase in funding in this area in Fiscal 1975. Ideally, DoD should have had ASUPT and some of the other R&D devices on line then because these systems are the tools we need to provide the answers on how much is enough and how to best fit simulators into the training program.

While it is wished it had been sooner, we are also thankful that predecessors had the foresight to begin these programs

FLARE

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An instructor in the Synthetic Flight Training System at Ft. Rucker, Alabama, explains the 2B24 UH-1 helicopter instrument flight trainer operator/instructor console to a technical chief at the Rucker Field Unit of the Army Research Institute.

in the late 1960s because they are now indeed producing results, and our R&D laboratories are providing expert consultative advice by extrapolation from known findings to influence present procurements.

The history of simulator development and its use in training programs for weapon systems described earlier shows that both the development and use of simulators and the maintenance of the quality of our flying force has been evolutionary.

In the past, DoD has procured and used simulators based on the technology available and on an assessment of how much simulation is needed. Defense has also supported the advance of technology. The Department is still in this evolutionary mode both in developing technology and in the intelligent use of simulators. DoD expects this evolution to continue.

It should also be noted that despite the increased interest in simulator usage, DoD's R&D program has suffered funding problems as recently as in FY 76. However, we believe that most of our problems in funding an aggressive simulation program are now largely behind us and we are taking vigorous actions to insure that we make the best possible use of the funds allocated for this area.

Finally, R&D results are useless if they are not well communicated to the people responsible for making decisions concerning the procurement and use of simulators. DoD is taking management steps to improve this facet of the program. The key parts of Defense's simulator use program are now conducted by R&D organizations at training bases, and we are moving still further in this direction as a result of the DoD Laboratory Utilization Study. Service interactions are improving, and it is noteworthy that we have cross-Service liaison representatives at most of our key simulation R&D facilities.

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